

**Anionic water-in-water polymer dispersions,  
processes for the preparation thereof, and the use thereof**

The present invention relates to processes for the preparation of anionic water-in-water polymer dispersions which contain at least one finely distributed, water-soluble and/or water-swellaable polymer A and a continuous aqueous phase which contains at least one polymeric dispersing agent B, to the water-in-water polymer dispersions obtainable thereby and to their use as auxiliaries in papermaking and/or as flocculating agents for the sedimentation of solids.

One of the fundamental problems when using a water-soluble polymeric flocculating agent is that of adequately dissolving this polymeric flocculating agent in water so that it can be used for the intended purpose.

Thus, very early on, water-soluble polymers were made available as dilute aqueous solutions. In the early 1970s, water-in-oil emulsions were introduced. Using the water-in-oil technology, it was possible to prepare high molecular weight polymers which dissolved very rapidly in water, such that this technology found great acceptance with the manufacturers of water-soluble polymers. The disadvantage of this water-in-oil technology was, however, that these emulsions contained substantial amounts of hydrocarbon liquid in the form of oils, whose incorporation into systems in which water-soluble polymers are conventionally used was only possible to a limited extent.

A further development of water-soluble polymeric flocculating agents involved the provision of processes for the preparation of dispersions of water-soluble cationic polymers. These polymers were prepared in an aqueous salt or a salt solution in which the polymer was insoluble. A disadvantage of such processes described, for example, in US 4 929 655 and US 5 006 590 is that these processes are virtually restricted to the preparation of dispersions of cationically charged water-soluble polymers which contain a proportion of a hydrophobic modified cationic monomer.

By contrast, these processes cannot be transferred without problems to the preparation of anionically charged water-soluble polymers, which are conventionally used as flocculating agents and as dewatering agents and retention auxiliaries in the paper industry.

In US 5 837 776, a process for the preparation of water-soluble anionic dispersion polymers is described, by means of which aqueous dispersions of water-soluble nonionically and anionically charged vinyl and allyl addition polymers were obtained by polymerization in the presence of an anionically charged water-soluble polymeric stabilizing agent in a saturated salt solution at a pH of from 2 to 5. The salt content of these dispersions is from 5 to 40 % by weight, based on the total weight of the dispersion, the proportion of the stabilizing agent being from 0.1 to 5 % by weight, based on the total weight of the dispersion. These polymeric anionically charged stabilizing agents have a molecular weight of from 100,000 to 500,000 and are preferably polymers and copolymers of acrylamidomethylpropanesulfonic acid (AMPS), which is present in the polymers to an extent of at least 20 mol%.

US 6 265 477 describes an aqueous dispersion of a disperse high molecular weight water-soluble anionic or nonionic polymer, which is obtained by polymerization of at least one anionic and nonionic monomer in the presence of an anionically charged water-soluble polymeric stabilizing agent, which contains from 1.25 to 20 mol% of acrylamidomethylpropanesulfonic acid and has a molecular weight of from 100,000 to 500,000, in an aqueous solution of a water-soluble salt at a pH of greater than 5, the salt content of these dispersions being from 5 to 40 % by weight.

In order to obtain water-in-water dispersions that are easier to handle, the preparation of cationic water-in-water polymer dispersions in the prior art has been repeatedly described. By way of example, attention is called here to the patent specifications WO 98/14405, WO 98/31748, WO 98/31749, and EP-A-0 630 909. A disadvantage of these water-in-water-polymer dispersions is that they are subjected, at more than 25 °C to 50 °C to changes which result in an impairment of the advantageous properties of the water-in-water dispersions and can lead, for example, to prolonged dewatering times. By contrast, the water-in-water-polymer dispersions prepared according to the process described in DE-A-100 61 483 have virtually unchanged utility properties, even after storage under extreme conditions, such as at temperatures of more than 25°C to 50°C. The preparation of these water-in-water-polymer dispersions is carried out here by subjecting monomers which are dispersed

in an aqueous phase which contains the water-soluble dispersing agent B, to free-radical polymerization, if appropriate with the addition of a water-soluble salt, and, on completion of the polymerization of the water-in-water dispersion, adding a water-soluble acid. The acid is in this case added in amounts of from 0.1 % to 5 % by weight and the salt in amounts up to not more than 3 % by weight, in each case based on the total dispersion, the acid and the salt together being added in amounts of not more than 5 % by weight, based on the total dispersion.

There is, however, still a need for stable high molecular weight water-in-water-polymer dispersions which are easy to handle, can be metered directly, and are stable in storage, which require no mineral oil and contain only small amounts of, or no, salt, which can be employed advantageously for solid/liquid separation in multifarious fields of application, in particular as flocculating agents or flocculating auxiliaries for sedimentation, filtration, and flotation, preferably in the papermaking industry.

It is therefore an object of the present invention to provide such a process, in which anionic water-in-water-polymer dispersions are obtained which even after storage have virtually unchanged utility properties and also possess adequate stability to hydrolysis in an alkaline medium and can in particular be used in multifarious retention systems in the papermaking industry.

The object is achieved according to the invention by a process for the preparation of anionic water-in-water polymer dispersions which contain at least one finely divided, water-soluble and/or water-swellaable polymer A and a continuous aqueous phase, this phase containing an aliquot of at least one polymeric dispersing agent B, in which monomers which are dispersed in this aqueous phase are subjected to free-radical polymerization and after completion of the polymerization the reaction mixture is subsequently diluted with the residual amount of the dispersing agent B.

"Anionic" water-in-water polymer dispersion is for the purposes of the invention to be understood as meaning a water-in-water polymer dispersion whose total charge is negative.

For the preparation of the water-in-water-polymer dispersions according to the invention, the monomers which are to be subjected to free-radical polymerization, preferably as an aqueous monomer solution, are finely divided in an aqueous phase which contains an aliquot of at least one polymeric dispersing agent B.

According to the invention, these polymeric dispersing agents are of relatively low molecular weight and have an average molecular weight  $M_w$  of not more than 250,000 g/mol, in particular of from 25,000 to 250,000 g/mol, preferably from 50,000 to 100,000 g/mol and more preferably 65,000 g/mol, measured according to the GPC method (gel permeation chromatography using 1.5% strength formic acid as an eluent against pullulan standards).

Furthermore, these polymeric dispersing agents contain at least one of the functional groups selected from ether groups, carboxyl groups, sulfone groups, sulfate ester groups, amino groups, amido groups, imido groups, tert-amino groups, and/or quaternary ammonium groups.

As examples thereof mention may be made of cellulose derivatives, polyvinyl acetates, starch, starch derivatives, dextrans, polyvinylpyrrolidones, polyvinylpyridines, polyethylenimines, polyamines, polyvinylimidazoles, polyvinylsuccinimides, polyvinyl-2-methylsuccinimides, polyvinyl-1,3-oxazolid-2-ones, polyvinyl-2-methylimidazolines and/or their respective copolymers with maleic acid, maleic anhydride, fumaric acid, itaconic acid, itaconic anhydride, (meth)acrylic acid, salts and/or esters of (meth)acrylic acid and/or (meth)acrylamide compounds.

Preferably, the polymeric dispersing agents B employed are anionic polymers which are synthesized from at least 30 % by weight, preferably at least 50 % by weight, more preferably 100 % by weight, of anionic monomer units which are derived from anionic monomers, such as, for example,

- olefinically unsaturated carboxylic acids and carboxylic acid anhydrides, in particular acrylic acid, methacrylic acid, itaconic acid, crotonic acid, glutaconic acid, maleic acid and maleic anhydride, fumaric acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof
- olefinically unsaturated sulfonic acids, in particular aliphatic and/or aromatic vinylsulfonic acids, for example vinylsulfonic acid, allylsulfonic acid, styrenesulfonic acid, acrylic and methacrylic sulfonic acids, in particular sulfoethyl acrylate, sulfoethyl methacrylate, sulfopropyl acrylate, sulfopropyl methacrylate, 2-hydroxy-3-methacryloxypropylsulfonic acid and 2-acrylamido-2-methylpropanesulfonic acid, and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof
- olefinically unsaturated phosphonic acids, in particular, for example, vinyl- and

- allyl-phosphonic acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof
- sulfomethylated and/or phosphonomethylated acrylamides and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof.

Preferably, the polymeric dispersing agents B employed are the water-soluble alkali metal salts of acrylic acid, polypotassium acrylates being particularly preferred according to the invention.

For the process according to the invention, it is essential to the invention that first only an aliquot of the polymeric dispersing agent B is employed, preferably 60 to 95 % by weight, based on the total amount of dispersing agent, while the remaining amount of dispersing agent B is added for subsequent dilution after completion of the polymerization and cooling of the reaction mixture B. An aliquot of less than 5 % by weight, based on the total dispersion, is inadequate for obtaining the anionic water-in-water-polymer dispersions of the invention.

In one embodiment of the process according to the invention, at least one water-soluble, polymeric dispersing agent B is employed together with a water-soluble polyfunctional alcohol and/or its reaction products with fatty amines. In particular, polyalkylene glycols, preferably polyethylene glycols, polypropylene glycols, block copolymers of propylene/ethylene oxide, having molecular weights of from 50 to 50,000, preferably from 1,500 to 30,000, low molecular weight polyfunctional alcohols such as glycerol, ethylene glycol, propylene glycol, pentaerythritol, and/or sorbitol are suitable for use as polyfunctional water-soluble alcohols and/or their reaction products with fatty amines containing from 6 to 22 carbons in the alkyl or alkylene radical.

The aqueous phase in which the monomers are dispersed, preferably in the form of an aqueous solution, must contain an adequate aliquot of water-soluble polymeric dispersing agent B and if appropriate, of a polyfunctional alcohol and/or said reaction product, in order that the polymer A that is formed during the reaction remains dispersed and an uncontrolled growth of the polymer particles and/or an agglomeration of the polymer particles formed is prevented.

Preferably, the polymeric dispersing agent B and the optionally present further dispersing agent components are employed in amounts of from 5 to 50 % by weight,

preferably from 5 to 30 % by weight and more preferably from 5 to 15 % by weight , based on the total weight of the dispersion.

When using further water-soluble dispersing agent components together with the polymeric dispersing agent B, a weight ratio of the polymeric dispersing agent B to these components should be in the range of from 1.00 : 0.01. In particular, a weight ratio of from 1.00 : 0.01 to 1.00 : 0.50 and preferably from 1.00 : 0.01 to 1.00 : 0.30 should be maintained.

The monomers which are preferably present in a finely and homogeneously dispersed form in the aqueous phase containing the polymeric dispersing agent B can comprise anionic, nonionic, amphiphilic and ethylenically unsaturated monomers, but also cationic monomers. In this case, in particular when using cationic monomers, the concentration thereof is to be chosen such that the total charge of the water-in-water-polymer dispersions prepared by the process according to the invention is negative. Moreover, in the case of an optionally present amount of water-insoluble monomers, these are chosen such that the water solubility or the water swellability of the polymer A obtained after the polymerization is not impaired.

The anionic monomers which can be used or selected by way of example according to the invention are those listed below:

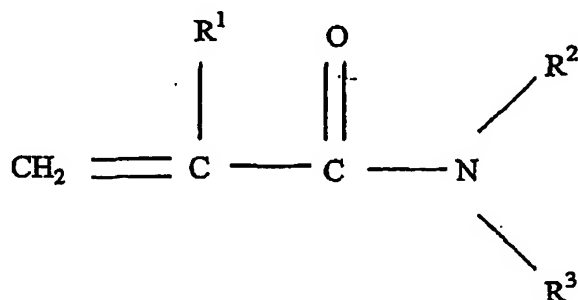
- a.) olefinically unsaturated carboxylic acids and carboxylic acid anhydrides, in particular acrylic acid, methacrylic acid, itaconic acid, crotonic acid, glutaconic acid, maleic acid, maleic anhydride, fumaric acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof
- b.) olefinically unsaturated sulfonic acids, in particular aliphatic and/or aromatic vinyl-sulfonic acids, for example vinylsulfonic acid, allylsulfonic acid, styrenesulfonic acid, acrylic and methacrylic sulfonic acids, in particular sulfoethyl acrylate, sulfoethyl methacrylate, sulfopropyl acrylate, sulfopropyl methacrylate, 2-hydroxy-3-methacryloxypropyl-sulfonic acid and 2-acrylamido-2-methylpropanesulfonic acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof
- c.) olefinically unsaturated phosphonic acids, in particular, for example, vinyl- and allyl-phosphonic acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof

- d.) sulfomethylated and/or phosphonomethylated acrylamides and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof.

Preferably, olefinically unsaturated carboxylic acids and carboxylic acid anhydrides, in particular acrylic acid, methacrylic acid, itaconic acid, crotonic acid, glutaconic acid, maleic acid, maleic anhydride, fumaric acid, and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof are employed as anionic monomers, the water-soluble alkali metal salts of acrylic acid, in particular its sodium and potassium salts and its ammonium salts, being particularly preferred.

When using 2-acrylamido-2-methylpropanesulfonic acid (AMPS) as the anionic monomer or the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof, it should be noted that the higher the amount of 2-acrylamido-2-methylpropanesulfonic acid and its salts in the high molecular weight phase, ie polymer A, the more pasty the dispersion according to the invention, and amounts of AMPS above 2 % by weight can lead to subsequent thickening of the dispersion on storage at elevated temperatures.

Nonionic monomers used for the preparation of the polymers A are, for example, compounds of the general formula (I)



(I)

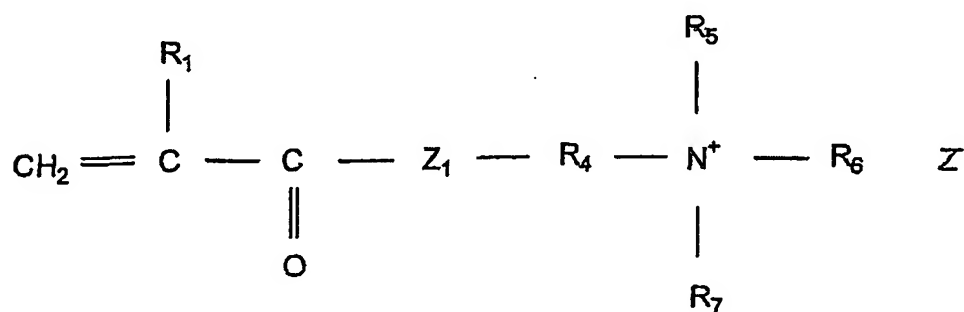
in which

- $\text{R}^1$  stands for a hydrogen radical or a methyl radical, and  
 $\text{R}^2$  and  $\text{R}^3$  independently of one another stand for hydrogen, or an alkyl or hydroxyalkyl radical of 1 to 5 carbon atoms, and  
 $\text{R}^2$  or  $\text{R}^3$  stands for an OH group,

Preferably, (meth)acrylamide, N-methyl(meth)acrylamide, N-isopropyl(meth)acrylamide or N,N-substituted (meth)acrylamides, such as N,N-dimethyl(meth)acrylamide, N,N-diethyl(meth)acrylamide, N-methyl-N-ethyl(meth)acrylamide or N-hydroxyethyl(meth)acrylamide, are employed.

According to the invention, advantageously the nonionic monomers employed can in particular be the water-soluble or water-dispersible derivatives of acrylic and methacrylic acid such as, for example, acrylamide, methacrylamide, and n-alkyl-substituted acrylamides. According to the invention acrylamide is very particularly preferred as a nonionic monomer.

The amphiphilic monomers used are compounds of the general formula (II)

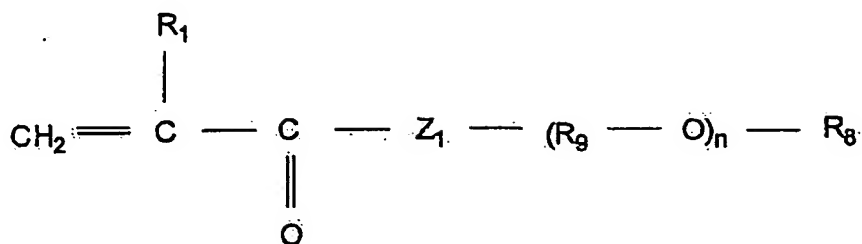


(II)

wherein

- $Z_1$  stands for O, NH,  $NR_4$ , wherein  $R_4$  denotes alkyl containing 1 to 4 carbon atoms,
- $R_1$  stands for hydrogen or a methyl radical,
- $R_4$  stands for alkylene containing 1 to 6 carbon atoms,
- $R_5$  and  $R_6$  independently stand for an alkyl radical containing 1 to 6 carbon atoms,
- $R_7$  stands for an alkyl, aryl, and/or aralkyl radical containing 8 to 32 carbon atoms and
- $Z^-$  stands for halogen, pseudohalogen,  $SO_4CH_3^-$  or acetate

or compounds of the general formula (III)



(III)

wherein

$\text{Z}_1$  stands for O, NH,  $\text{NR}_4$ , wherein  $\text{R}_4$  denotes alkyl containing 1 to 4 carbon atoms,

$\text{R}_1$  stands for hydrogen or a methyl radical,

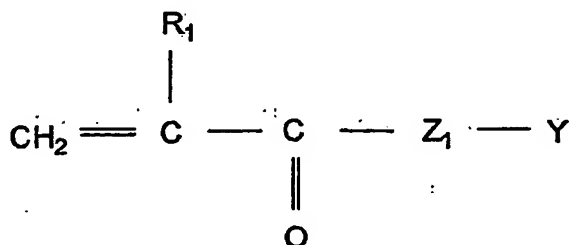
$\text{R}_8$  stands for hydrogen, an alkyl, aryl and/or aralkyl radical containing 8 to 32 carbon atoms,

$\text{R}_9$  stands for an alkylene radical containing 2 to 6 carbon atoms

$n$  stands for an integer from 1 to 50.

Preferably, these are reaction products of (meth)acrylic acid with polyethylene glycols (10 to 40 ethylene oxide units), which are etherified with fatty alcohol, or the corresponding reaction products with (meth)acrylamide.

Suitable cationic monomers which can optionally likewise be employed for the preparation of the polymers A, whose use takes place under the premise that the total charge of the water-in-water polymer dispersions prepared by the process according to the invention is negative, are compounds of the general formula (IV)



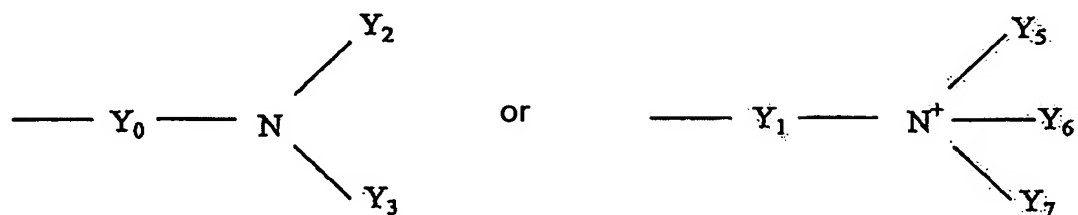
(IV)

in which

$R_1$  stands for hydrogen or a methyl radical,

$Z_1$  stands for O, NH or  $NR_4$  where  $R_4$  stands for an alkyl radical containing 1 to 4 carbon atoms,

$Y$  stands for one of the groups



wherein

$Y_0$  and  $Y_1$  stand for an alkylene radical or hydroxyalkylene radical containing 2 to 6 carbon atoms,

$Y_2, Y_3, Y_4, Y_5, Y_6, Y_7$ , independently stand for an alkyl radical containing 1 to 6 carbon atoms,

$Z^-$  stands for halogen, acetate, or  $SO_4CH_3^-$ .

Preferably, suitable protonated or quaternized dialkylaminoalkyl are (meth)acrylates or dialkylaminoalkyl (meth)acrylamides containing from 1 to 3 carbons in the alkyl or alkylene groups, more preferably the methyl chloride-quaternized ammonium salt of dimethylaminoethyl (meth)acrylate, dimethylaminopropyl (meth)acrylate, dimethylaminoethyl (meth)acrylate, diethylaminoethyl (meth)acrylate, dimethylaminomethyl (meth)acrylate dimethylaminoethyl(meth)acrylamide and/ or dimethylaminopropyl(meth)acrylamide.

For the preparation of polymer A, a monomer composition is used which consists of from 0 to 100 % by weight, preferably of from 5 to 70 % by weight and more preferably from 5 to 40 % by weight of anionic monomers, in each case based on the total weight of monomer. Very preferably, the preparation of polymer A is carried out using a mixture of nonionic monomers, preferably acrylamide and anionic monomers, in particular olefinically unsaturated carboxylic acids and carboxylic acid anhydrides, preferably acrylic acid, methacrylic acid, itaconic acid, crotonic acid, glutaconic acid, maleic acid, maleic anhydride, fumaric acid and the water-soluble alkali metal salts thereof, alkaline earth metal salts thereof, and ammonium salts thereof, acrylic acid

being particularly preferred as the anionic monomer.

A mixture of acrylic acid with alkyl (meth)acrylates and/or alkyl (meth)acrylamides is also preferred.

In such monomer compositions, the amount of anionic monomers is preferably at least 5 % by weight.

The monomers or the aqueous solution thereof are dispersed in an amount of from 5 to 30 % by weight and preferably from 10 to 30 % by weight, based on the total weight of the solution or the resulting total dispersion, in the aqueous phase containing an aliquot of at least one dispersing agent B. For example, an aqueous monomer solution has a concentration of 5 to 60 % by weight, preferably 10 to 50% by weight, based on the total aqueous monomer solution. The high molecular weight polymer A is subsequently formed from the monomers by polymerization.

The polymers A prepared by the process according to the invention are of high molecular weight, but are nevertheless water-soluble or water-swellaable polymers having an average molecular weight  $M_w$ , measured by the GPC method, of  $> 1.0 \times 10^8$  g/mol, the average molecular weight  $M_w$  of the polymer A always being greater than that of the polymeric dispersing agent B.

The polymeric dispersing agent B and the polymer A, however, differ from each other, the difference being a consequence of the respective physical characteristics, in particular of their different molecular weights and/or of their chemical structure, eg due to the use of different monomer compositions.

According to the invention, preferred water-in-water polymer dispersions contain as a dispersing agent a potassium or sodium acrylate having a molecular weight of about 65,000 g/mol (determined by means of gel permeation chromatography) or as monomer units for the high molecular weight phase, ie polymer A, acrylamide (80 % by weight), potassium, ammonium or sodium acrylate (20 % by weight) are employed.

The polymerization can be optionally carried out in the presence of a water-soluble salt by the process according to the invention. If the addition of water-soluble salts is intended, ammonium, alkali metal and/or alkaline earth metal salts, preferably ammonium, sodium, potassium, calcium and/or magnesium salts can in particular be

employed. Such salts can be salts of an inorganic acid or of an organic acid, preferably of an organic carboxylic acid, sulfonic acid, phosphonic acid, or of a mineral acid. The water-soluble salts of aliphatic or aromatic mono-, di- or polycarboxylic acids, hydroxycarboxylic acids, in particular of acetic acid, propionic acid, citric acid, oxalic acid, succinic acid, malonic acid, adipic acid, fumaric acid, maleic acid, and benzoic acid or sulfuric acid, hydrochloric acid or phosphoric acid, are preferred. Very preferably, sodium chloride, ammonium sulfate, and/or sodium sulfate are used as water-soluble salts.

The addition of the salt to the system can take place prior to polymerization, during polymerization, or after polymerization. The addition of the salt prior to polymerization of the monomer is preferred.

If a salt is used in the preparation of the water-in-water polymer dispersion, this salt is added in amounts of up to not more than 3.0 % by weight, preferably in amounts of from 0.5 to 2.5 % by weight and more preferably in amounts of from 0.75 to 2.0 % by weight, in each case based on the total dispersion.

To carry out the process of the invention, the continuous aqueous phase is prepared by dissolving or diluting the aliquot of the polymeric dispersing agent B, optionally a polyfunctional alcohol, and/or a corresponding reaction product with fatty amines in water and dispersing the monomers or the aqueous solution thereof according to known dispersion methods, preferably by stirring.

The monomers of the polymer A can be introduced directly into the continuous aqueous phase as such or preferably as an aqueous monomer solution.

The monomer solution in general contains from 5 to 80 % by weight and preferably from 10 to 50 % by weight, based on the total solution, of monomers and the remaining amount is water with auxiliaries optionally present therein, such as, for example, chelating agents. To start the polymerization, for example, free-radical initiators, so-called polymerization initiators, are used. The free-radical initiators preferably employed are azo compounds, such as, for example, 2,2-azobisisobutyronitrile, 2,2-azobis(2-aminopropane) dihydrochloride or preferably potassium persulfate, ammonium persulfate, hydrogen peroxide, if appropriate in combination with a reducing agent, such as, for example, an amine or sodium sulfite. The amount of initiator, based on the monomers to be polymerized, is in general from

$10^{-3}$  to 1 % by weight and preferably from  $10^{-2}$  to 0.1 % by weight. The initiators can be added all at once at the commencement of the polymerization or alternatively only portionwise with a subsequent metering of the residual amount throughout the polymerization. Likewise, the monomers or the monomer solution can be dispersed all at once or only as an aliquot of the dispersing agent B at the commencement of the polymerization, the remainder of the monomers or monomer solution being added in metered portions or as a continuous supply with dispersion throughout the polymerization. Moreover, it is also possible to carry out the preparation of the water-in-water-dispersions according to the process of EP-A-0 664 302, the relevant disclosure of which is incorporated herein by reference. Essentially, in this procedure water is eliminated during the polymerization and, if appropriate, polymeric dispersing agent B is added.

The polymerization temperature is in general from 0 to 120 °C and preferably from 30 to 90 °C. Preferably, the polymerization is carried out such that the system is flushed with inert gas and the reaction mixture is polymerized under a blanket of inert gas, eg under a blanket of nitrogen. The polymerization conversion or the termination of the polymerization can be ascertained in a simple manner by determining the residual monomer content. The methods for accomplishing this are known to the person skilled in the art.

Following polymerization, the reaction mixture is, according to the invention, subsequently diluted with the residual amount of the dispersing agent B. It is advantageous to cool the reaction mixture, preferably to  $\leq 35$  °C and to subsequently dilute it with from 5 to 50 % by weight, preferably from 10 to 40 % by weight and more preferably from 20 to 35 % by weight of dispersing agent B, based on the total amount thereof. This subsequent dilution step is obligatory, as otherwise the anionic water-in-water polymer dispersions according to the invention would not be obtained.

The water-in-water-polymer dispersions obtainable according to the invention or the process for their preparation are an advantageous alternative to the known anionic, high molecular weight polyacrylamide/polyacrylate copolymers, which are prepared either as granules or as liquid water-in-oil emulsions. The water-in-water polymer dispersions are a highly concentrated, effective liquid system not containing mineral oil or surfactants, which has a good storage stability even at relatively high environmental temperatures and is, moreover, nonflammable. It has no volatile organic content (VOC) and the chemical or biological oxygen demand is extremely

low compared with the corresponding emulsions. The products according to the invention have outstanding solubility in water and are also suitable undiluted for direct metering in an application.

Due to these properties, and, in particular, due to the fact that the water-in-water polymer dispersions according to the invention are easy to handle, directly meterable, storage-stable dispersions, which require no mineral oil and contain only small amounts of, or no, salt, they can be employed advantageously for solid/liquid separation, preferably in aqueous systems, in multifarious fields of application.

For example, they can be used as flocculating agents for flocculating auxiliaries for sedimentation, filtration and flotation, preferably in water and process water purification or waste water purification, in the recovery of raw material, in particular coal, aluminum, or petroleum, or as a demulsifier in the separation of oil-containing and/or fat-containing water mixtures and more preferably in the papermaking industry as auxiliaries in paper production, especially in cationic paper pulps.

Furthermore, the water-in-water polymer dispersions can be used in retention agent systems such as, for example, in the form of single component systems, soluble two-component systems and microparticulate systems. The choice of aforementioned system to be used here depends on various factors, such as, for example, the fibrous material composition and the type of filler, but in particular on the nature and amount of the undesirable substances present in the paper pulp.

In single component systems, these being the simplest retention systems, the use of the anionic water-in-water-polymer dispersions according to the invention in cationic paper suspensions causes aggregation of the cationic solids in the suspension.

Since the increasing batches of waste paper and very frequent occurrences of shutdown of the water circulations in papermaking plants produce a constantly growing freight of unwanted substances which in some cases can no longer be controlled using single component systems, it is known to meter two different retention agents as a so-called soluble two-component system. The first component used in such a case is a low molecular weight polymer and, the second component, a high molecular weight cationic or anionic polyacrylamide follows. Furthermore, there are systems in which the two components are mixed beforehand to give a dual system and are added together to the paper pulp.

Advantageously, the water-in-water-polymer dispersions according to the invention can be metered not only on their own, but also as so-called dual systems (anionic/cationic or cationic/anionic) to such paper pulps. It is a special advantageous that in this case the water-in-water polymer dispersions according to the invention can be made to order as a single product customized for this particular purpose, so that it is no longer necessary to mix the components to create the dual system required.

With respect to the use of the water-in-water-polymer dispersions according to the invention, it may be pointed out. by way of explanation, that microparticulate systems conventionally consist of two components, namely a water-soluble cationic polymer and a colloiddally dissolved or suspended anionic microparticulate component, the latter having a large specific surface area. In papermaking, the cationic polymer is then added first, for example immediately upstream or downstream of the flowbox pump or upstream of the vertical screen. This causes partial covering of the fiber and filler surfaces, because of which the total charge can definitely still be negative:

Subsequently, anionic microparticles are added, and the site of addition should be as close as possible to the flow box. They react with the cationic polymers accumulated on the fiber and filler surfaces and form a kind of bridge. A fine dense flock having a reversible formation character is obtained.

Preferably, the anionic water-in-water dispersions according to the invention can be used for paper machines which are used for the production of moisture-resistant/strongly brightened paper qualities, such as, for example, laminate papers, label papers, but also in some cases tissue papers or special papers (e.g. banknotes). Advantageously, the water-in-water dispersions according to the invention make possible, in particular with respect to granules, better sheet formation. Moreover, it has been found that the use of the water-in-water polymer dispersions, in particular in the paper industry, is extremely economical. Thus an industrial large-scale experiment, in which the water-in-water polymer dispersions were used as flocculating agents in the production of label papers, showed that in this assay showing a consumption of 60 kg/day of the anionic water-in-water dispersions it was possible to lower the pulp loss through the hopper from 8 to 10 t/day to < 1 t/day.

Furthermore, the water-in-water-polymer dispersions according to the invention are very highly suitable for the treatment of paint waste waters or can be used in waste

water treatment plants of factories comprising a number of paper machines which produce different types of paper.

Moreover, the water-in-water polymer dispersions according to the invention can also be used in raw water purification (surface water).

## **Methods**

### **1. Determination of the solution viscosity**

For the determination of the solution viscosity of the water-in-water dispersions prepared according to the invention, a 5 % strength solution of the dispersions is prepared. 340 g of the 5 % strength solution is needed for the measurement. To this end, the necessary amount of demineralized water is introduced into a 400 ml beaker. Subsequently, the water introduced is stirred with a pencil stirrer so vigorously that a cone forms which extends to the bottom of the beaker. The amount of water-in-water dispersion necessary for the preparation of the 5 % strength solution is injected into the stirred water as a single dose by means of a disposable syringe. The solution is subsequently stirred at 300 rpm ( $\pm 10$  rpm) for one hour. After a standing time of 10 minutes, the Brookfield viscosity is determined with the aid of an RVT-DVII Brookfield viscometer using a spindle 2 at speed 10.

### **2. Determination of the salt viscosity**

289 g of completely demineralized water are weighed into a 400 ml beaker. Subsequently, the water introduced is stirred so vigorously with a pencil stirrer that a cone forms which extends to the bottom of the beaker. 17 g of the water-in-water dispersion prepared according to the invention are injected into the stirred water as a single dose by means of a disposable syringe. After the water-in-water dispersion has dissolved, 34 g of sodium chloride (technical) are strewn in. After stirring at 300 rpm ( $\pm 10$  rpm) for 16 minutes, the solution is allowed to stand for a further 10 minutes. Subsequently, the Brookfield viscosity is determined with the aid of a Brookfield RVT-DV II viscometer using spindle 1 at speed 10.

## **Examples**

In the following examples, which are only intended to illustrate the invention, the solution or salt viscosity, the flocculating value and the dewatering action are determined by the methods indicated above. The term solution is always to be understood as meaning an aqueous solution.

### **General procedure**

0.5 g of pentasodium diethylenetriaminepentaacetate (40% strength), 210.0 g of a dispersing agent (37% strength) and, if appropriate, ammonium sulfate are added to

a solution of 272.0 g of acrylamide (50% strength) and 27.4 g of acrylic acid in water after pH adjustment using a 25% strength ammonia solution (or if appropriate using 50% strength sulfuric acid). The mixture is added to a 2 liter flask having a stirring apparatus (KPG stirrer) and heated to a temperature of 40 °C. After freeing from oxygen by blowing through nitrogen, 91 ppm of an azo initiator (as a 10% strength solution) and 73 ppm of an oxidant (as a 4% strength solution) are added. On reaching the temperature maximum  $T_{max}$ , a further 364 ppm of an azo initiator are added and the mixture is then allowed to react at this temperature for 15 min. After cooling to room temperature, the mixture is subsequently diluted with 100 g of polypotassium acrylate (37% strength).

The polymer content of the dispersion (15.5 % dispersed phase and 10.4 % dispersing agent based on the total dispersion) is kept constant independently of the salt concentration and amount of dispersing agent etc., if appropriate by adjustment of the amount of water.

All percentage data are in percentages by weight, based on the total dispersion.

The product viscosity 2 after storage at room temperature is determined after one day.

After 5 days, the condition of the w/w dispersions is assessed after storage at 40°C. Experiments in which the thickening point during the reaction became critical for the stirrer and apparatus were terminated prematurely.

**Table 1: Influence of the amount of salt**

(at pH = 6 with polypotassium acrylate as the dispersing agent)

Ex. No.	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	Product viscosity 1 as prepared	Product viscosity 2 after storage	Δ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
	[g]	[%]	[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
1	0	0	14200	26600	12400	liquid	2290	720
2	5	0.45	14400	27400	13000	liquid	2240	709
3	10	0.91	15200	21200	6000	liquid	1690	610
4	16.5	1.5	15600	22000	6400	liquid	1960	710
5	22	2	16200	24800	8600	solid in 10 days	1800	790
6	55	5	21600	37200	15600	solid	1000	550
7	110	10	17700	30900	13200	solid	780	560
8	165	15	17400	xxx	xxx	solid	xxx	xxx

**Result:**

An increased salt concentration does not have a positive effect. At a salt concentration of about 0.9 to 1.5 %, the subsequent thickening behavior at room temperature (Δ) is minimal and this is an altogether comparatively low product viscosity. The products are also storage-stable at elevated temperature.

**Table 2: Influence of the pH**

(Example 11 corresponds to Example 3; the dispersing agent is polypotassium acrylate)

Ex. No.	pH	Product viscosity 1 as prepared	Product viscosity 2 after storage	Δ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
		[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
9	3	xxx	xxx	Xxx	solid	xxx	xxx
10	5	xxx	xxx	Xxx	solid	xxx	xxx
11	8	15200	21200	6000	liquid	1690	610
12	7	18200	25400	7200	liquid	1620	610
13	9	11200	xxx	Xxx	solid	1300	490

**Result:**

The polymerization should be carried out in a pH range of from 6 to 7.

**Table 3: Influence of the amount of dispersing agent B**

(The amounts of polyacrylate mentioned in the general procedure, in this case of poly-potassium acrylate based on Example 18 (corresponds to Example 3) were varied,  $M_w = 65.000$  g/mol).

Ex. No.	Poly-potassium acrylate	Poly-potassium acrylate	Poly-potassium acrylate subsequent dilution	Poly-potassium acrylate subsequent dilution	Total poly-potassium acrylate	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	Storage at 40°C	Solution viscosity	Salt viscosity
	[g]	[%]	[g]	[%]	[%]	[mPas]	[mPas]		[mPas]	[mPas]
14	88.73	2.98	0	0	2.98	xxx	xxx	xxx	xxx	xxx
15	147.88	4.97	0	0	4.97	xxx	xxx	xxx	xxx	xxx
16	310	10.43	0	0	10.43	110,000	xxx	xxx	xxx	xxx
17	130	4.37	180	6.05	10.42	xxx	xxx	xxx	xxx	xxx
18	210	7.06	100	3.36	10.42	15200	21200	liquid	1690	610

**Result:**

Amounts of dispersing agent as an additive before polymerization of less than 5 % by weight are not adequate, even if after completion of the polymerization it is still subsequently diluted. The subsequent dilution (division of the amount of dispersing agent) is obligatory.

**Table 4: Influence of the molecular weight of the dispersing agent B**

(Example 19 corresponds to Example 3; the dispersing agent is polypotassium acrylate)

Ex. No.	$M_w$ Dispersing agent	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
	[g]	[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
19	65,000	15200	21200	6000	liquid	1690	610
20	75,000	17600	24500	6900	liquid	1400	500
22	95,000	xxx	xxx	xxx	solid	xxx	xxx
23	130,000	xxx	xxx	xxx	solid	xxx	xxx
24	170,000	xxx	xxx	xxx	solid	xxx	xxx

**Result:** The optimal molecular weight range for the dispersing agent B is not more than about 75,000 g/mol.

**Table 5: Variation of the counterion of the dispersed polymer phase A**

For neutralization, KOH (45 % strength) and NaOH (50 % strength) are used instead of ammonia (25 % strength). Example 24 corresponds to Example 3. The dispersing agent is polypotassium acrylate.

Ex. No.	Counterion polymer A	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
		[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
24	NH <sub>4</sub> <sup>+</sup>	15200	21200	6000	liquid	1690	610
25	NH <sub>4</sub> <sup>+</sup>	17100	23300	6200	liquid	2140	740
26	K <sup>+</sup>	13100	n.b.	n.b.	liquid	1400	500
27	K <sup>+</sup>	12500	16600	41000	liquid	1650	750
28	Na <sup>+</sup>	13400	n.b.	n.b.	liquid	1360	550
29	Na <sup>+</sup>	15500	21900	6700	liquid	1600	620

**Result:** All counterions can be used for polymer A.

**Table 6: Influence of the temperature on the subsequent dilution**

(Example 32 corresponds to Example 3; the dispersing agent is polypotassium acrylate)

Ex. No.	Temperature subsequent dilution	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
	[°C]	[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
30	T <sub>max</sub> (ca 75)	21000	32700	11700	liquid	1770	650
31	45	15600	22600	7000	liquid	1820	690
32	< 30	15200	21200	6000	liquid	1690	610

**Result:** It is particularly advantageous to effect subsequent dilution below 30 °C

**Table 7: Influence of the subsequent treatment on the residual monomer content**

(Examples 30 to 32 correspond to Example 3)

Example No.	Measurement	Residual monomer content of acrylic acid	Residual monomer content of acrylamide
		[ppm]	[ppm]
33a	Prior to subsequent treatment	2140	3620
33b	Following subsequent treatment with VA044	980	490
33c	Subsequent treatment with VA044	720	290
33d	Subsequent treatment with ABAH	830	330

**Result:**

The residual monomer content is markedly reduced by a subsequent treatment of the dispersion.

**Table 8: Influence of AMPS Na in the high molecular weight phase**

(Polypotassium acrylate is the dispersing agent; Example 36 corresponds to Example 3)

Ex. No.	AMPS-Na	AMPS-Na	Product viscosity 1 as prepared	Product viscosity 2 after storage	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
	[g]	[%]	[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
36	0	0	15200	21200	6000	liquid	1690	610
37	10.2	0.93	14300	23000	8700	liquid	1860	710
38	20.4	1.85	16200	23600	7400	liquid	1900	740
39	30.8	2.78	14600	20100	5500	liquid to pasty	1600	730
40	50.1	4.64	13400	17000	3600	liquid to pasty	1370	750
41	68	6.18	8000	17700	9700	liquid to pasty	800	560

**Result:**

The higher the proportion of AMPS Na in the high molecular weight phase, the more pasty the dispersion. Amounts of AMPS greater than 2 % by weight lead to subsequent thickening on storage at higher temperatures.

**Table 9: Influence of the counterions of the dispersing agent B**

(Example 42 corresponds to Example 3; Mw= 65.000 g/mol)

Ex. No.	Counterion low molecular weight phase	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
		[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
42	K <sup>+</sup>	15200	21200	6000	liquid	1690	610
43	Na <sup>+</sup>	42000	pasty	xxx	solid	1630	600
44	NH <sub>4</sub> <sup>+</sup>	xxx	xxx	xxx	xxx	xxx	xxx

**Result:** For the dispersing agent B, the K<sup>+</sup> ion is best suited as a counterion.**Table 10: Concentration of the product during the preparation (*analogously to EP 0 664 302 Bi*) followed by subsequent dilution with dispersing agent B.**

Examples 61 to 63 were prepared as Example 3; but after reaching the thickening point a vacuum of 250 mbar is applied and water is distilled off at a temperature of 70°C (see Table 12). The reaction apparatus is subsequently let down to standard pressure and dispersing agent B is correspondingly replaced. After cooling to room temperature, the mixture is treated as usual.

Polymer content of Example 62 (15.5 % of disperse phase and 12.1 % of dispersing agent based on the total dispersion).

Polymer content of Example 63 (15.5 % of disperse phase and 13.8 % of dispersing agent based on the total dispersion).

Ex. No.	Vacuum	[g] of water distilled off	Product viscosity 1 as prepared	Product viscosity 2 after storage at RT	$\Delta$ p.v. 1 – p.v. 2	Storage at 40°C	Solution viscosity	Salt viscosity
	[mbar]	[g]	[mPas]	[mPas]	[mPas]		[mPas]	[mPas]
61	1020	0	15200	21200	6000	Liquid	1690	610
62	250	50	7600	10800	3200	Liquid	1460	540
63	250	100	4840	6280	1440	liquid	1320	530

**Result:** It is advantageous to remove water by distillation and to replace it by dispersing agent B.